Chapter 18
Fuzziness in Ant Colony Optimization and Their Applications

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ABSTRACT

Nature-inspired algorithms are still at a very early stage with a relatively short history, comparing with many traditional, well-established methods. Metaheuristics, in their original definition, are solution methods that orchestrate an interaction between local improvement procedures and higher level strategies to create a process capable of escaping from local optima and performing a robust search of a solution space. One major algorithm is Ant Colony Optimization which has been applied in varied domains to better the performance. Fuzzy Linear Programming models and methods has been one of the most and well-studied topics inside the broad area of Soft Computing. Its applications as well as practical realizations can be found in all the real-world areas. Here we wish to introduce how fuzziness can be included in a nature inspired algorithm like ant colony optimization and thereby enhance its functionality. Several applications of ACO with fuzzy concepts will be introduced in the chapter.

1. INTRODUCTION

Since the fuzzy boom of the 1960s, methodologies based on fuzzy sets (Mousa, 2014) have become a permanent part of all areas of research, development and innovation, and their application has been extended to all areas of our daily life: health, banking, home, and are also the object of study on different educational levels. Similarly, there is no doubt that thanks to the technological potential that we currently have, computers can handle problems of tremendous complexity (both in comprehension and

DOI: 10.4018/978-1-5225-2857-9.ch018

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dimension) in a wide variety of new fields. Also since the mid 1970s, GA (or EA from a general point of view) have proved to be extremely valuable for finding good solutions to specific problems in these fields, and thanks to their scientific attractiveness, the diversity of their applications and the considerable efficiency of their solutions in intelligent systems, they have been incorporated into the second level of soft computing components. EA, however, are merely another class of heuristics, or metaheuristics, in the same way as Taboo Search, Simulated Annealing, Hill Climbing, Variable Neighbourhood Search, Estimation Distribution Algorithms (EDA), Scatter Search, GRASP, Reactive Search and very many others are. Generally speaking all these heuristic algorithms (metaheuristics) usually provide solutions which are not ideal, but which largely satisfy the decision-maker or the user. When these act on the basis that satisfaction is better than optimization, they perfectly illustrate Zadeh's famous sentence: "...in contrast to traditional hard computing, soft computing exploits the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, low solution-cost, and better rapport with reality". Consequently, among the soft computing components, instead of EA (which can represent only one part of the search and optimization methods used), heuristic algorithms and even metaheuristics should be considered. Consequently we could say that the most important second-level Soft Computing components are probabilistic reasoning, fuzzy logic and sets, neural networks and in view of what we have explained, metaheuristics (which would typically encompass EA but would not be confined to these exclusively). As it is patent, all these four main components have common factors as it is Data Mining, essential for learning process, as well as real applications.

2. METAHEURISTICS

The metaheuristics are by far the most popular and define mechanisms for developing an evolution in the search space of the sets of solutions in order to come close to the ideal solution with elements which will survive in successive generations of populations. In the context of soft computing, the hybridizations (Dubois et al, 1990) which take these metaheuristics as a reference are fundamental. A very active area of research is the design of nature-inspired metaheuristics. Many recent metaheuristics, especially evolutionary computation-based algorithms, are inspired by natural systems. Such metaheuristics include Ant colony optimization, particle swarm optimization, cuckoo search, and artificial bee colony to cite a few. Metaheuristics are used for combinatorial optimization in which an optimal solution is sought over a discrete search-space. An example problem is the travelling salesman problem where the search-space of candidate solutions grows faster than exponentially as the size of the problem increases, which makes an exhaustive search for the optimal solution infeasible. Additionally, multidimensional combinatorial problems, including most design problems in engineering (Kirkpatrick, 1983; Holland, 1976; Glover 1977) such as form-finding and behavior-finding, suffer from the curse of dimensionality, which also makes them infeasible for exhaustive search or analytical methods. Popular metaheuristics for combinatorial problems includesimulated annealing by Kirkpatrick et al., genetic algorithms by Holland et al., scatter search (Glover, 1986) and tabu search (Robbins, 1951) by Glover. Literature review on metaheuristic optimization, (Barricelli, 1954) suggested that it was Fred Glover who coined the word metaheuristics (Rastrigin, 1963).

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